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SOCIETAL RISK AROUND AMSTERDAM AIRPORT SCHIPHOL

AIR TRAFFIC DEVELOPMENT AND SPATIAL PLANNING BETWEEN 1990 AND 2005

Jos G. Post/National Institute of Public Health and the Environment *

Eelke S. Kooi/ National Institute of Public Health and the Environment

Johan Weijts/National Aerospace Laboratory

SUMMARY/ABSTRACT

The societal risk in the area around Amsterdam Airport Schiphol was investigated for the period 1990−2005. Societal risk usually refers to the total area of interest. For Schiphol this would mean a square of 56 km by 56 km, so that the contribution of specific locations to the societal risk is unclear. This study therefore made use of map squares of 100 m by 100 m to provide a more detailed insight of the contribution of specific locations to the societal risk.

The most prominent populations considered in the study were those located in residential, business or industrial areas. The contributions of these individual population types to societal risk were considered on a comparative basis; considerable effort went into developing an appropriate population data set for 1990 and the current situation.

The main conclusions of the study are that: 1) since 1990 the societal risk due to air traffic has nearly doubled; 2) there is a strong geographical concentration, as 90% of the societal risk is located in 4% of the built-up areas; and 3) the increase in societal risk is mainly due to the increase in air traffic and in the number of employees in the area.

Future increases in this risk can be regulated by limiting new business or residential developments in zones with restrictions on noise and safety. Only business parks with very high population densities can result in new locations with a relatively high societal risk. This also includes locations outside the restrictions area.

* Corresponding author: jos.post@rivm.nl

INTRODUCTION

Safety and risk around Amsterdam Airport Schiphol has been an issue for many years. As Europe's fourth largest airport, it handled 411,000 flights and 44 million passengers in 2004[1] [schiphol 2004]. This implies that on average there are more than 60 flights an hour during daytime, either landing or take-off. Moreover Schiphol is located between the main cities of the Netherlands and some 3 million people (almost one-fifth of the Dutch population) live in the greater Schiphol area. Although air transportation is a safe business, accidents cannot be excluded. There has been one major accident in the history of Schiphol. In 1992 a 747 cargo plane lost two engines from one wing after take-off. Upon attempting to return to the airport to make an emergency landing it lost its stability and crashed into an apartment building about 10 stories high. Besides the deaths of the crew there were another 39 casualties on the ground. The Dutch authorities have developed a risk-based policy to deal with this so-called external safety or third party risk. In the mid-1990s a 'stand still' policy promised that the environmental issues (noise, air pollution, safety) would be kept at the level of 1990 [1], whilst still allowing an increase in air traffic. Between 1990 and 2004 the annual number of air traffic movements grew from 207,000 to 411,000 [2]. To accommodate this growing number of flights a new fifth runway has been in use since 2003. This will allow the airport to grow to about 600,000 annual flights (physical capacity). At the same time the development of housing, industry and business in the Schiphol area has only been limited in very strict zones near the runway heads. Outside these zones, but still close to the airport, a large number of business locations have been developed. Not surprisingly, politicians recently discovered that the 'stand still' policy had been an illusion. In the future, air traffic and urban developments will continue to be a dynamic ensemble in the field of third party risk. Existing instruments for policy development and spatial planning must therefore be reviewed and new ones developed. The study presented here was carried out for the Ministry of Housing, Spatial Planning and the Environment and examines the consequences of air traffic and spatial developments between 1990 and 2010 on third party risk. It also assesses the suitability of new policy options for controlling external safety around Schiphol.

AIR TRAFFIC RISK

There are several models for calculating third party risk for air traffic [3, 4]. In the Netherlands a model developed by NLR [5] is used. The main parameters considered in this model are the flight accident rate, the accident location with respect to the flight path and runway, and the consequences of an accident (crash area and lethality in this area given an accident). The accident rate is related to the age of the aircraft: three generations are distinguished from the 1950s up to now, and the rate is lowest of course for the third generation. The effect area is linear to the maximum take-off weight (MTOW). With this model the risk is calculated in terms of individual and societal risk.

Individual risk (IR) is a measure of the probability of being killed by an aircraft accident at a specific location. Individual risk can be plotted on a map as lines of equal risk (iso-risk contours). Societal risk (SR) is a measure for the possibility of a group (of a certain number) of people on the ground being killed in one accident. A large group of people killed in a single event (e.g. an aircraft accident) has a bigger impact on society than the same number of people being killed 'one after another' in, for example, car accidents. One drawback of societal risk is that it is not a geographical quantity, in other words it cannot be 'put on the map'. In this study a new method for presenting societal risk in geographical terms is discussed. Risk levels are calculated and displayed on a grid of 1 ha squares. With such a detailed analysis it is possible to show the contribution of specific locations to overall societal risk, and to evaluate the impact of future developments on societal risk.

The greater Schiphol area is shown in Figure 1. In this figure the IR 10^{-5} yr^{-1} and 10^{-6} yr^{-1} are depicted together with the restrictions area for land-use-planning. A societal risk curve can be calculated for the greater Schiphol area as shown in Figure 2. This so-called FN curve shows the probability (F) of an accident occurring with more than N fatalities. The dashed line in the curve is the Dutch guideline value for chemical plants and installations (GVCI). This GVCI is in fact the line, in the double logarithmic plot, through the points $F = 10^{-5}$ yr^{-1} for $N = 10$ and $F = 10^{-7}$ yr^{-1} for $N = 100$ ($F \times N^2 = 10^{-3}$). Although this GVCI is used for chemical plants in the Netherlands and not for an airport like Schiphol, it has nevertheless been used as a reference value for map squares of 100 m by 100 m.

According to the recent Airport Zoning Decree [6] of 2002, land-use planning around Schiphol is partly risk-based. The areas enclosed by the IR 10^{-5} yr^{-1} and 10^{-6} yr^{-1} contours are very close to the runway heads. In the highest risk zone (10^{-5} yr^{-1}) only existing business, agricultural and industrial buildings are allowed. In the 10^{-6} yr^{-1} zone,

[1] Only flights with take-off weight more than 5700 kg are included

only existing buildings including houses are allowed. A larger area is the so-called restrictions zone. This zone is mainly determined by the area for which there are limits on building heights and in which bird-attracting activities are forbidden (both in accordance with ICAO[2] rules). Besides the IR 10^{-5} yr^{-1} and 10^{-6} yr^{-1} zones, which are restrictions zones for land-use planning, there is also another risk-based limit for the use of the airport. This is the so-called total risk weight (TRW): product of the average accident rate per flight and the summed maximum take-off weight (both per year). In other words: the expected weight of 'aeroplane' dropping accidentally to the ground per year. For Schiphol this is 9.724 tons. This TRW is only dependent on the number of flights and the accident rate. It is not location specific and it is not dependent on the population density.

Figure 1. Risk contours and restrictions area of Schiphol Airport

DEVELOPMENT OF SOCIETAL RISK

Societal risk is a combination of two things. There must be a source of risk (air traffic) and a 'society' exposed to this risk (people in houses or at work near flight paths). Societal risk can therefore change as a result of these two things. At and around Schiphol airport both factors have been changing over the past fifteen years. The number of flights[3] has risen from about 207,000 in 1990 to about 411,000 in 2004. However in this period, the total risk weight only increased from about 5 to 6 tons. This is because, at least at Schiphol and other large European airports, planes without modern standard navigation and safety equipment and planes making too much noise have been banned. In practice this airport safety and noise policy has excluded the older planes.

The development of the overall societal risk was shown in Figure 2. As the figure is 'double logarithmic' the change appears to be modest. The table below Figure 2, however, shows that between N = 10 and N = 40 the probability almost doubles and for N = 100 the increase is nearly 70%.

[2] ICAO: International Civil Aviation Organization
[3] One flight is one take-off or one landing

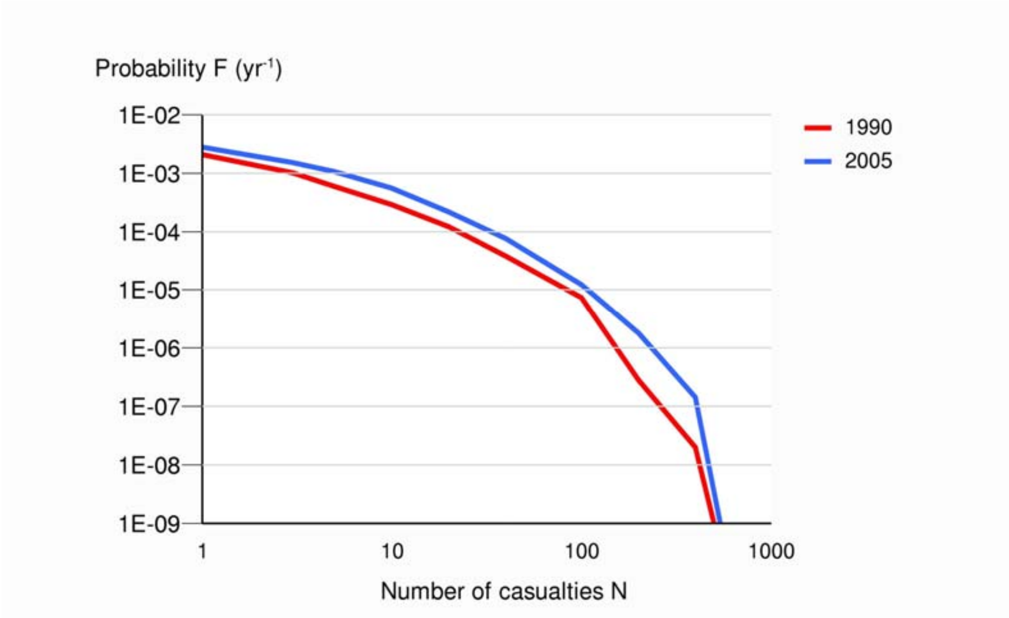

Figure 2. **Societal risk curve for Schiphol, for 56 km by 56 km area**

Table 1. Count of map squares for probability categories

Probability	Number of map squares	Sum (%)	Cumulation (%)
larger than 1 GVCI	20	38.6	38.6
between 0.1 and 1 GVCI	160	37.2	75.8
between 0.01 and 0.1 GVCI	620	14.2	90.0
	other	10.0	100

For N >40 GVCI = 6.25×10^{-7} yr^{-1}
Total probability $7.6\ 10^{-5}$ yr^{-1}
Highest risk at one map squares $3.4\ 10^{-6}$ yr^{-1}

The societal risk was calculated for all map squares of 100 m by 100 m, as described in the section "Air traffic risk". In Figure 3, the map shows the probability of an accident with more than 40 casualties on the ground. To obtain an idea as to which levels of societal risk are problematic for 100 m by 100 m map squares, these local risk levels were compared with the guideline values for societal risk around chemical plants (GVCI). The GVCI is expressed as $F \times N^2 = 10^{-3}$, and the GVCI is applied to the whole surroundings of the chemical plant (typically 1−5 km^2). As the map squares in this study are much smaller (0.01 km^2), levels of 1% GVCI are considered to be relevant. Together these squares of 1% GVCI add up to 80–100% of the total societal risk of air traffic around Schiphol (depending on N, the number of fatalities). The result is summarized in Table 1.

Both Figure 3 and Table 1 clearly show that the societal risk is mostly concentrated in a very small number of map squares [4]. Some 90% of the SR is located in just 800 squares. In the past, the greater Schiphol area has always been considered (56 km by 56 km). This area contains 238,000 map squares of 1 ha (large water areas excluded) and 38,271 squares with a relevant building density (at least 10 people ha^{-1}). The 800 squares with 90% of the risk therefore represent just 2% of the total built-up area.

[4] The geographical information can best be looked at in colour and at large computer displays instead of black and white printout.

Figure 3. Probability of more than 40 casualties (2005)

Figure 4. Probability for more than 40 casualties (1990)

The development of the societal risk from 1990 to 2005 is a result of the growth in air traffic and the increase in the residential and business populations. The flight paths have also changed over the years, with the fifth runway commissioned in 2003 forming the biggest change. The map in Figure 4 shows the probability for N >40 in the reference year 1990. Just as for 2005, it is clear that the societal risk is concentrated in a small number of map squares. Some 86% of the risk is present in about 460 squares. A careful examination of the maps (Figure 3 and 4) shows that the number of marked squares has increased between 1990 and 2005. This difference is predominantly due to 'new' squares appearing, although at some locations squares have disappeared. The disappearance of squares is mostly due to changed flight paths as a result of the fifth runway being used. Figure 5 shows how the

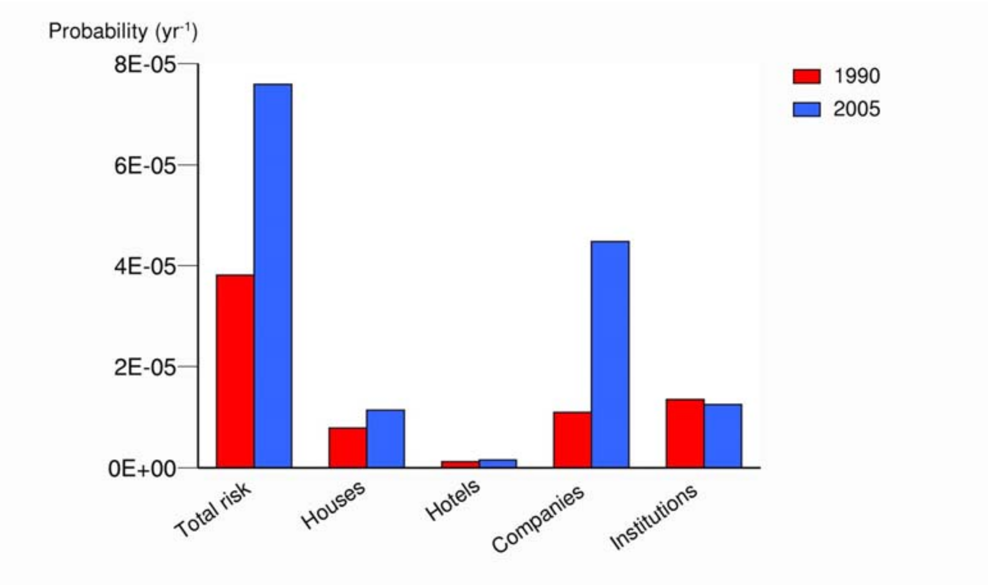

Figure 5. Development of the probability for more than 40 casualties for different types of buildings

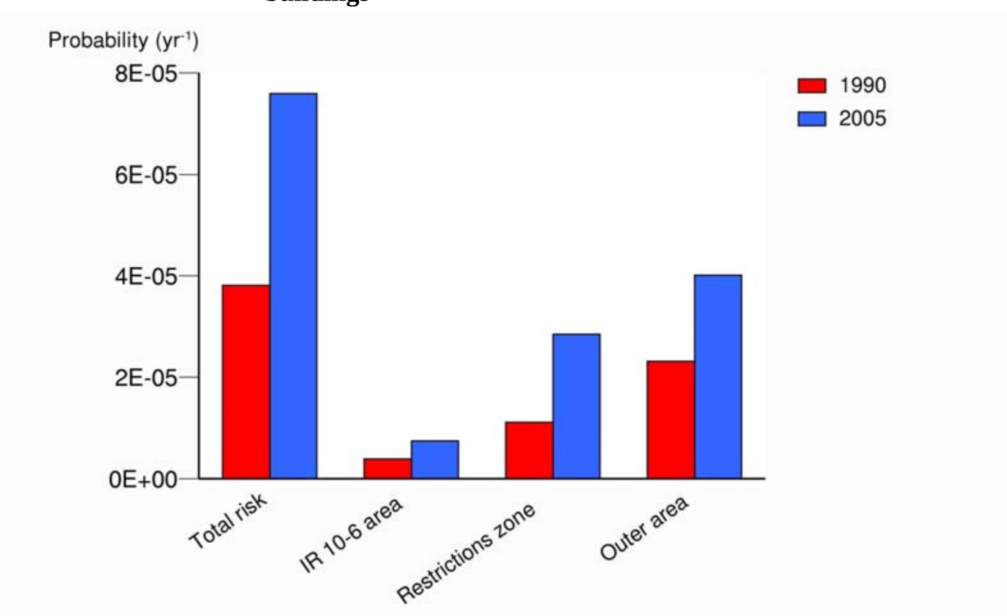

Figure 6. Development of the probability for more than 40 casualties for different zones

societal risk has developed from 1990 to 2005 in terms of building functions and Figure 6 in terms of geographical areas. From these figures it can be concluded that the societal risk has almost doubled from 1990 to 2005. A large part of this increase is due to business locations close to the runways. This is hardly surprising in view of the many airport-related developments that have been realized around Schipol over the past 10 to 20 years, such as offices with international operations and cargo-handling companies.

FUTURE DEVELOPMENTS IN LAND USE

There are several ways in which the insights from this study can be used in future land-use developments. For example it can be calculated whether a new residential area or business park will result in a new ‘hot spot’ on the map. Such developments should be called into question if the societal risk expressed as the probability for N > 40 is higher than 0.1 GVCI on the 100 m by 100 m map squares. The choice of 0.1 GVCI as a ‘limit’ requires further study and a decision concerning this will need to be taken at a policy level.

Figure 7 shows another alternative for using the approach of this study in future land-use developments. In this figure the whole area of 56 km by 56 km is filled up with residential developments of about 70 persons ha^{-1}. New ‘red’ zones can be seen on the map. In these zones the societal risk, for N >40, is more than 1% (light red) or more than 10% (dark red) of the GVCI. Fortunately the red zones are almost completely inside the restrictions area and no new residential developments are allowed there. New residential developments outside the restrictions area will not lead to new concerns for societal risk. However, the same approach for business parks with a high population density of 225 persons ha^{-1} does lead to ‘red’ zones outside the restrictions area. This indicates that for future business park developments, the expected societal risk situation should be carefully considered.

Figure 7. Areas of concern for new residential developments with a population of 70 persons ha^{-1}.

CONCLUSIONS

Up until now, societal risk in the greater Schiphol area as a result of air traffic have always been presented with a so-called societal risk curve (FN curve) for the total area. This type of presentation provides no information as to where the societal risk is located on the map. In this study societal risk is calculated and presented for map squares of 100 m by 100 m. This allows the contribution of residential and business areas to societal risk to be established. Societal risk for aircraft accidents is related to the guideline value for fixed chemical plants. With this the societal risk of air traffic can be compared, as an indication, to the societal risk of other types of major accidents.

The main conclusions of this study are:

- Societal risk, expressed as the probability of an accident involving either more than 10 or more than 40 casualties, has nearly doubled in 2005 compared to 1990.
- Geographically, the societal risk is very much concentrated in a limited number of map squares. About 90% of the risk is located in 800 map squares (8 km^2 in total).
- This risk can be regulated by limiting new business or residential developments in the restrictions area. Only business parks with a very high density can result in new locations with a relatively high societal risk. This also includes locations outside the restrictions area.

Current research is exploring the options to extend the restrictions zone for high-density building developments.

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